

**SUPPORTING A CIRCUIT PACKAGE INCLUDING A SUBSTRATE
HAVING A SOLDER COLUMN ARRAY**

Background

5 Ever since the advent of the first computer, there has been an unending drive to make computers and their components smaller, faster, and more powerful. These goals have created a whole new array of engineering concerns such as making a high number of robust electrical connections in very small spaces as well as providing for near-zero tolerance flatness of component casings. Other concerns include selecting materials to minimize differences in the coefficients of thermal expansion between the different types of conductive and non-conductive materials used in electronic components.

10 One type of computer-based electronic component is a column grid array integrated circuit package. These packages can be electrically connected and secured to a printed circuit board via an array of solder columns that extend from the integrated circuit package for connection to the printed circuit board. The material and dimensions of these solder column arrays generally accommodate the difference in thermal expansion between the printed circuit board and the integrated circuit package, which contributes to their strong joint reliability.

15 However, large integrated circuit packages also require large thermal solutions, such as heat sinks, which in turn place significant long-term static compressive loads on the solder columns. Moreover, in order to attach the appropriate sized thermal solution (e.g. heat sink) to the substrate and to insure a good thermal interface between the heat sink and the integrated circuit package, a significant retention load must be placed on the package. With a large integrated circuit package, the solder columns cannot bear this long-term static compressive load for very long without exhibiting creep, and ultimately some form of failure mode, such as buckling, bending, and/or solder joint disruption. In particular, any load of more than about 10-20 grams per solder column will exceed the limits of the solder columns. In addition, solder columns experience short-term dynamic loading from shock and vibration during shipping and/or during mobile use. For these reasons, column grid array packages having solder

columns arrays have limited application for interconnecting large or high power integrated circuit packages on printed circuit boards.

One attempt at overcoming these issues includes placing non-conductive, rigid column supports underneath the substrate of the integrated circuit packages

5 to help bear the high retention load that is required. The load is translated through the substrate to the rigid column supports, which are positioned side-by-side with the solder columns to help bear the long-term, static compressive load.

For example, see U.S. Patent 6,541,710, titled **METHOD AND APPARATUS OF SUPPORTING CIRCUIT COMPONENT SOLDER COLUMN ARRAY**

10 **USING INTERSPERSED RIGID COLUMNS.** However, to gain sufficient support from the rigid column supports, the integrated circuit package needs to be slightly larger to accommodate the non-conductive column locations within the contact array. Since space on the printed circuit board is at a premium, larger package sizes are less desirable.

15 Other attempts at supplementing mechanical support for solder column arrays include setting a shim underneath a portion of the integrated circuit package and using an epoxy adhesive to fix the shim in place relative to the package. Using an epoxy adhesive can be messy, difficult to precisely place, slow due to curing time, and can introduce additional stress and strain issues

20 because the epoxy is fixed relative to the package and the shim. In addition, with an epoxy in place, it becomes difficult to remove the package in the event that reworking of the circuit board becomes necessary. Finally, adding an epoxy adds yet another material parameter to the already delicate task of matching coefficients of thermal expansion between materials of the substrate, solder

25 columns, and printed circuit board.

Accordingly, solder column arrays remain a limiting factor in the size and power of integrated circuit packages that can be used in the column grid array configuration.

Summary

30 One aspect of the present invention provides a method of supporting, on a printed circuit board, a circuit package including a substrate having a solder column array. The method comprises providing the circuit package with an

over-sized lid that extends outwardly over an edge of the substrate. The circuit package is electrically connected to the printed circuit board via the solder column array and a plurality of supports are secured to the printed circuit board in position underneath the lid of the circuit package while leaving a gap between 5 the lid and the support. A static compressive force is applied and maintained to the circuit package relative to the printed circuit board, thereby causing the solder column array to creep until the gap is closed and a substantial portion of the compressive force is borne by the supports.

10

Brief Description of the Drawings

Figure 1 is an isometric view of an electronic component system using a corner support for solder column arrays, according to an embodiment of the present invention.

15

Figure 2 is a partial sectional view of Figure 1, according to an

embodiment of the present invention.

Figure 3 is a sectional view of an electronic component system prior to implementing a solder column array support, according to an embodiment of the present invention.

20

Figure 4 is sectional view of the electronic component system during

initial application of a compressive force, according to an embodiment of the present invention.

Figure 5 is a sectional view of the electronic component system during long term application of the compressive force, according to an embodiment of the present invention.

25

Figure 6 is an isometric view of an alternate securing mechanism for a support, according to an embodiment of the present invention.

Figure 7 is a partial sectional view of an alternate support of electronic component system, according to an embodiment of the present invention.

30 8—8.

Detailed Description

In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as "top," "bottom," "front," "back," "leading," "trailing," etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments of the present invention can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

Figure 1 illustrates electronic component system 10 according to one embodiment of the present invention, which comprises printed circuit board 12, column grid array package 14, heat sink 18, and supports 40. Printed circuit board 12 carries a variety of electronic components, such as a plurality of column grid array packages, just one of which is shown in Figure 2. Figure 1 also shows a compressive force F acting on system 10. A mechanism for supplying this force is not shown in Figure 1 to accentuate illustration of a package support of the present invention. However, mechanisms for supplying this force are further described and illustrated in association with Figures 4 and 8.

Column grid array package 14 includes substrate 15 having edge 17, over-sized lid 16, and solder column array 30. Column grid array package 14 is any electronic integrated circuit package for use in a circuit carried on printed circuit board 12 and that uses a solder column array for interconnection to printed circuit board 12. For example, column grid array package 14 can be a very large scale integration (VLSI) integrated circuit, such as a central processing unit (CPU) or application specific integrated circuit (ASIC), as well as other types of integrated circuits.

Edge 17 of substrate 15 of package 14 defines a periphery of substrate 15 while lid 16 extends outwardly over edge 17 of substrate 15. Solder column array 30 includes a plurality of solder columns 31 and extends from package 14 to electrically and mechanically connect package 14 to an electrically conductive contact array of printed circuit board 12 such as lead-free materials. Solder columns 31 are made of 90/10 solder, or other suitable material that provide good electrically conductivity, proper solder flow during soldering, and that exhibit predictable stress, strain, and creep characteristics.

Each package support 40 includes a pair of wing portions 42 and main body 44. Wing portions 42 extend outwardly from main body 44 and are generally perpendicular to each other. Wing portions 42 are sized and shaped to fit between lid 16 of package 14 and printed circuit board 12. Wing portions 42 support any load translated through lid 16 of package 14, such as the mass of heat sink 18, as well as a compressive load applied on system 10 by compression springs and/or plates, as further described and illustrated in association with Figure 8. This support eliminates tension on solder columns 31 in a dynamic environment, like shock and vibration, and insures an optional thermal interface. Main body 44 of each support 40 is sized and shaped to receive a fastener (see Figure 2) such as a screw mounted through the back side of printed circuit board 12 and into the bottom of support 40. Alternatively, main body 44 optionally receives a fastener through a top surface of support 40 for securing into printed circuit board 12.

Figure 2 is a sectional view of Figure 1 taken along lines 2—2. As shown in Figure 2, each support 40 is secured to printed circuit board 12 with fastener 52, such as a screw or plug, through a mounting hole 54 in printed circuit board 12. Support 40 also optionally includes corner recess 56 which is sized and shaped to receive and make contact with corner 58 of package 14. As illustrated in Figures 1-2, lid 16 is over-sized (i.e., extending outwardly beyond edge 17 of substrate 15 of 14, to which lid 16 is coupled).

Supports 40 are not limited to the shape shown in Figure 2. For example, main body 42 can have other shapes that are appropriate to the type of fastener used to secure support 40 relative to printed circuit board 12.

Each support 40 is made from a plastic material, composite material, or a metallic material, with the material selected to have a coefficient of thermal expansion (CTE) that generally matches a coefficient of thermal expansion of substrate 15 of package 14 and solder columns 31. In particular, the material is
5 selected so that it does not expand faster than the combined coefficient of thermal expansion of substrate 15 and solder columns 31, thereby preventing the introduction of tension on solder columns 31. One composite material for constructing supports 40 includes aluminum silica carbide (ALSiC).

A method of using supports 40 of the present invention is shown in
10 Figures 3-5. Figures 3-5 illustrate a partial sectional view of system 10 of one corner of system 10. As shown in Figure 3, column grid array package 14 includes substrate 15 and over-sized lid 16 with heat sink 18 mounted thereon. Lid 16 extends outwardly over edge 17 of substrate 15. Solder column array 30 of package 14 extends down to printed circuit board 12 establishing both a
15 mechanical and electrical connection between package 14 and printed circuit board 12. Each solder column 31 of solder column array 30 has a height H1. Support 40 is positioned under lid 16 and has a height H2, such that a gap G, extends between lid 16 and support 40. Supports 40 are inserted underneath lid 16 after package 14 has been solder attached to printed circuit board 12 via
20 solder column array 30. Support 40 is secured against printed circuit board 12 via fastener 52.

As shown in Figure 3, H2 is greater than H1 so that support 40 does not extend underneath substrate 15 of package 14, and therefore support 40 does not directly support substrate 15. In this arrangement, any load caused by package
25 14, lid 16, and heat sink 18 is borne exclusively by solder column array 30. In addition, since supports 40 have a height H2 that is greater than height H1 of solder columns 31 (and greater than a distance between a bottom surface of package 14 and printed circuit board 12), supports 40 are limited to contacting edge 17 of substrate 15 rather than its bottom surface. This height feature of
30 supports 40 eliminates any chance for electrical contact between support 40 and solder columns 31, which would cause a short circuit.

As shown in Figure 4, in a first state of system 10, a long-term static compressive force F is applied on the components of system 10. The compressive force F generally is provided through a clamping mechanism (not shown) including springs, spring plate, load posts, compression screws, etc., to insure good thermal contact and to eliminate potential tension on solder columns 31 in dynamic environments. As this compressive force F is initially applied, gap G between lid 16 and support 40 remains for some period of time.

However, after some period of time, solder columns 31 of solder column array 30 begin to experience load creep under this compressive force F, causing solder columns 31 to deflect (i.e., decrease in height). In particular, solder columns 31 creep until they achieve a height H3, which is shown in Figure 5. Height H3 of solder columns 31 in this second state of system 10 is less than height H1 of solder columns in their first state (shown in Figure 3). With this decrease in the height of solder columns 31 from H1 to H3, gap G between lid 16 and printed circuit board 12 is closed. As gap G diminishes, a substantial portion of the compressive force F shifts from solder columns 31 to supports 40, thereby relieving solder columns 31 from exclusively bearing compressive force F and stopping creep on solder columns 31. In this second state, solder columns 31 still bear some load, which bolsters their joint reliability and electrical conductivity, and supports 40 bear a majority of compressive force F translated through over-sized lid 16. Nevertheless, at some point the load on solder columns 31 is sufficiently light that creep no longer acts on the solder columns, thereby preventing failure modes of bending, buckling, and/or solder joint disruption.

Accordingly, supports 40 removes the strength of solder columns 31 as a previously limiting constraint on the use of high compressive loads, which are used with large integrated circuit packages. Therefore, supports 40 of one embodiment of the present invention enable the use of solder column array interconnects for larger integrated circuit packages than was previously possible.

Supports 40 are implemented without the use of an epoxy to hold them in place relative to lid 16. This epoxy-free arrangement enhances the ability to match coefficients of thermal expansion between supports 40 and the rest of the

assembly, such as lid 16 and printed circuit board 12. Moreover, epoxy-free securing of supports 40 eases reworking of assembly, in the event that substrate needs to be replaced. In this scenario, supports 40 do not act as a constraint in removing package 14 since supports 40 act only to support a compressive load 5 toward printed circuit board 12 and do not restrict movement of package 14 and lid 16 away from printed circuit board 12.

As shown in Figure 6, in an alternate arrangement, supports 70 are held in place with band 80. Supports 70 comprise wing portions 72 and corner 74. In this arrangement, fasteners such as fasteners 52 shown in Figures 1-5, are not 10 used to secure supports 70 relative to package 14 and lid 16 and/or relative to printed circuit board 12. Accordingly, since supports 70 do not need to receive a fastener corner 74 of support 70 is much smaller than main body 44 of support 40. This feature of supports 70 conserves space on printed circuit board 12.

Upon initial insertion of supports 70 under lid 16, band 80 holds supports 15 70 in place. After a static compressive force (a retention load) is applied to system 10 and creep acts on solder column array 30, supports 40 bear a majority of compressive force exerted on assembly 10 so that this vertical compressive force, in addition to the lateral force of band 80, holds supports 40 in place under lid 16.

20 As shown in Figure 7, alternate support 100 includes main body 102 and detent 104. Printed circuit board 12 includes hole 110 that is sized and shaped for receiving detent 104. In use, support 100 is secured to printed circuit board 12 by pressing detent 104 of support 100 into hole 110 of printed circuit board 12. Detent 104 is shaped and sized, and optionally flexible, to permit 25 maneuvering of main body 102 of support under lid 16 while inserting detent 104 into hole 110. Detent 104 comprises a dimple, plug, or other shape that is configured for snap fitting into, or frictionally engaging, a portion of printed circuit board 12 to secure support 100 relative to printed circuit board 12. Hole 110 in printed circuit board 12 also can have other shapes, such as a slot, groove, 30 slanted hole, etc., to facilitate insertion of detent 104. Main body 102 of support 100 is smaller than main body 44 of support 40, since main body 102 only need carry detent 104 and need not provide receiving support of a fastener, such as a

screw. Accordingly, support 100 can further save space on printed circuit board 12.

Finally, while supports are shown implemented at corners of package 14, which enhances their stability and strength, supports optionally can be 5 implemented at locations other than the corners, such as along the sides of package 14.

Figure 8 is a modified sectional view of Figure 1 as taken along lines 8—8. Figure 8 shows an exemplary embodiment of a compressive force mechanism 150 for applying a static compressive force F to system 10, as is shown in 10 Figures 1 and 4-5. Supports 40, 70, and 100 of the present invention support this compressive force F to prevent it from damaging solder column array 30, as previously described. Supports 40, 70, 100 are not shown with the rest of system 10 for simplicity in illustrating compressive mechanism 150. This type of compressive mechanism, and other compressive mechanisms suitable for 15 applying a compressive force F as described in association with Figures 1-7 are disclosed in U.S. Patent 6,198,630, which is hereby incorporated by reference.

Compressive mechanism 150 comprises spring member 152 and compression screw 154. Compression screw 154 includes crown 156, threads 157, shaft 158, and end 159. Spring member 152 includes side walls 160, top wall 162, and ends 166. Spring member 152 is sized and shaped to fit over heat sink 18 of system 10, which is already mounted on package 14. Compressive mechanism 150 also optionally comprises a stiffening or backing plate for mounting on the opposite side of printed circuit board 12 to further support 20 system 10.

In use, with package 14 already solder attached to printed circuit board 12 via solder column array 30 and with heat sink already mounted on package 14, compressive mechanism 150 is applied. First, with spring member 152 positioned over heat sink 18, ends 166 of spring member 152 are removably inserted into holes 170 of printed circuit board 12, thereby fixing spring member 30 152 relative to printed circuit board. Compression screw 154 is then inserted through hole 164 in top wall 162 of spring member 152 to extend through a center portion of heat sink 18, with its end 159 resting within base 175 of heat

sink 18. As compression screw 154 is threadably inserted, compression screw 154 causes top wall of spring member 152 to deflect, which in turn applies a compressive force to heat sink 18 and the rest of system 10. Top wall 162 of compressive mechanism 150 is maintained at a desired level of deflection via 5 compression screw 154 to apply and maintain a desired static compressive force on system 10.

Accordingly, package supports of the present invention can be used as shims to shift high retention loads from the solder column arrays to the package supports, thereby liberating column grid array packages to be sized larger than 10 was previously possible due to the limited column strength of solder column arrays. In addition, by supporting an over-sized lid of the packages, the package supports can also reduce the load borne by the substrate of the package to further reduce bowing and stress on the delicate circuitry within the package. Finally, package supports can also take advantage of the limited creep of the solder 15 columns that occurs during gradual loading of the package supports to increase solder joint reliability of the solder columns.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific 20 embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.